

WHAT IS CLAIMED IS:

- 1                    1.        A device for suturing an end of a first body duct to a hole in the  
2        side of a second body duct, said device comprising:  
3                    a structure for holding the end of the first body duct and positioning said  
4        end adjacent to the hole in the side of the second body duct; and  
5                    a plurality of needles arranged on the structure to be advanced along a  
6        plurality of paths wherein each path first passes radially into and forwardly out of the end  
7        of the first body duct and into the hole of the second body duct and then everts so that the  
8        needles will pass outwardly through tissue peripheral to the hole when the end of the first  
9        body duct is on the structure adjacent to the hole in the second body duct.
- 1                    2.        A device as in claim 1, wherein the structure comprises a shaft.
- 1                    3.        A device as in claim 2, wherein the shaft has a surface adapted to  
2        receive the first body duct.
- 1                    4.        A device as in claim 3, wherein said surface comprises a  
2        cylindrical surface adapted to received the first body duct.
- 1                    5.        A device as in claim 2, wherein the shaft has a tubular surface  
2        against which the needles are positioned to guide said needles along a portion of said  
3        path.
- 1                    6.        A device as in claim 2, wherein the shaft further comprises a  
2        plunger for advancing said needles through the first body duct.
- 1                    7.        A device as in claim 6, wherein the plunger includes suture storage  
2        for a plurality of sutures each coupled to one of said plurality of needles.
- 1                    8.        A device as in claim 6, wherein the plunger comprises a plurality  
2        of elongate members for advancing said needles through the first body duct.
- 1                    9.        A device as in claim 8, wherein the elongate members comprise  
2        tubes each containing a suture coupled to one of said needles.
- 1                    10.       A device as in claim 1, wherein the structure comprises a plurality  
2        of guide channels which define said plurality of paths.

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1 11. A device as in claim 10, wherein the guide channels are arranged in  
2 a radial configuration about a shaft of said structure.

1 12. A device as in claim 10, wherein the guide channels comprise  
2 guide tubes.

1 13. A device as in claim 10, wherein the guide channels have a  
2 longitudinal slot along a length of at least of one said guide channels.

1 14. A device as in claim 10, wherein the guide channels each have a  
2 first portion and a second portion, wherein the first and second portions are separated by a  
3 gap which receives the end of the first body duct.

1 15. A device as in claim 10, wherein at least one of said guide channels  
2 has a substantially curved configuration so that one of said needles passing through said  
3 guide channel will evert to pass outwardly through tissue peripheral to the hole when the  
4 end of the first body duct is on the structure adjacent to the hole in the second body duct.

1 16. A device as in claim 14, wherein the second portion of the guide  
2 channel comprises a guide tube having a J-shaped section for guiding one of said needles  
3 along a portion of said path.

1 17. A device as in claim 16, wherein the second portion of the guide  
2 channel tube has a longitudinal slot extending along the length of the guide tube having a  
3 J-shaped section.

1 18. A device as in claim 14, wherein the first body duct has a lumen, a  
2 body duct wall, and an outer surface, and wherein:

3 the first portion of the guide channel is adapted to be positioned outside  
4 the first body duct and has a distal opening positioned to open towards an outer surface of  
5 the first body duct when the first body duct is mounted on the structure; and

6 the second portion of the guide channel is adapted to be positioned in the  
7 lumen of the first body duct when the first body duct is mounted on the structure, said  
8 second portion of the guide channel receiving one of said needles advanced from the first  
9 portion and passing through the body duct wall.

1 19. A device as in claim 18, wherein the second portion of the guide  
2 channel has a J-shaped configuration.

1 20. A device as in claim 18, wherein the second portion of the guide  
2 channel includes a longitudinal slot extending the length of the second portion.

1 21. A device as in claim 18, wherein the needles are of sufficient  
2 length to extend from the first portion of the guide channel, through the second portion,  
3 and through the tissue layer of the second body duct.

1 22. A device as in claim 1, wherein said needles comprise a shape-  
2 memory alloy.

1 23. A device as in claim 1, wherein said needles comprise a  
2 superelastic material.

1 24. A device as in claim 1, wherein:  
2 said needles each have an arcuate profile when unconstrained;  
3 said structure comprises a tubular constraint having a lumen surface,  
4 wherein the needles are movable between a first position within the tubular constraint  
5 where said needles have a substantially straight configuration and a second position  
6 within the constraint wherein said needles extend beyond the tubular constraint and  
7 assume said arcuate profile.

1 25. A device as in 24, wherein said tubular constraint comprises an  
2 inner tube coaxially mounted with an outer tube, said needles mounted on the distal end  
3 of the inner tube wherein said inner tube is movable between a first and second position  
4 with the outer tube.

1 26. A device as in claim 1, wherein the structure comprises:  
2 an outer tube having a passage; and  
3 an inner tube slidably mounted in the passage of the outer tube and having  
4 the needles fixedly secured to a distal end thereof, said needles adapted to penetrate one  
5 end of the first body duct when the body duct is mounted within said inner tube.

1 27. A device as in claim 26, wherein:  
2 said needles each have an arcuate profile when unconstrained;

3           said inner tube is movable between a first position within the outer tube  
4       where said needles have a substantially straight configuration and a second position  
5       within the outer tube wherein said needles extend beyond the outer tube and assume said  
6       arcuate profile.

1           28.     A device as in claim 26, wherein the inner tube has an opening in a  
2       wall of the inner tube spaced apart from a distal end of the inner tube, said opening  
3       allowing for the insertion of the first body duct into a lumen of the inner tube.

1           29.     A device as in claim 26, wherein the inner tube is coupled to a  
2       plunger which reciprocates said inner tube between a forwardly advanced position and a  
3       retracted position.

1           30.     A device as in claim 26, wherein the outer tube and inner tube are  
2       in coaxial alignment and have a slideable relationship relative to each other.

1           31.     A device as in claim 26, wherein each of said needles has a suture  
2       attached to the distal end of said needles.

1           32.     A device as in claim 26, wherein the needles have arcuate shape  
2       memory so that they evert as they are advanced forward.

1           33.     A device as in claim 32, wherein the needles have a sharpened tip  
2       pointing proximally when the needles are in a substantially curved configuration.

1           34.     A device as in claim 32, wherein said needles comprise a shape  
2       memory material.

1           35.     A device as in claim 26, wherein the needles in said second  
2       position has a length sufficient to extend from the inner tube through a wall of the second  
3       body duct such that a sharpened tip of the needle penetrates completely through said wall.

1           36.     A device as in claim 26, wherein the needles have a releasable  
2       connection with said inner tube.

1           37.     A device as in claim 1, further comprising means for guiding said  
2       needles through the first and second body ducts.

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1                   38.     A device as in claim 37, wherein the means for guiding the needles  
2 comprises a plurality of guide channels.

1                   39.     A device as in claim 37, wherein the means for guiding the needles  
2 comprises a plurality of needles having an arcuate profile when unconstrained and  
3 mounted within a tubular constraint, said needles movable between a first position where  
4 the tubular constraint forces the needles to a substantially straight configuration and a  
5 second position wherein the needle assumes a configuration exhibiting said arcuate  
6 profile.

1                   40.     A method for suturing an end of a first body duct to a hole in the  
2 side of a second body duct, said method comprising:  
3                   positioning the end of the first body duct adjacent to the hole in the second  
4 body duct;  
5                   advancing a plurality of needles carrying a plurality of sutures along a  
6 plurality of paths, wherein each path first passes radially into and forwardly out of the end  
7 of the first body duct and into the hole of the second body duct and then everts so that the  
8 needles will pass outwardly through tissue peripheral to the hole when the end of the first  
9 body duct is on the structure adjacent to the hole in the second body duct; and  
10                  securing a portion of at least one of said sutures outside of the first body  
11 duct to a portion of the suture outside of the peripheral tissue surrounding the hole in the  
12 second body duct.

1                   41.     A method as in claim 40, wherein said positioning step includes  
2 mounting said first body duct against a shaft structure containing said plurality of needles.

1                   42.     A method as in claim 40, wherein advancing the needles comprises  
2 passing the needles through guide channel which define the paths.

1                   43.     A method as in claim 42, wherein the guide channels each have a  
2 first portion and a second portion, where the first and second portions are separated by a  
3 gap which receives the end of the first body duct.

1 44. A method as in claim 43, wherein advancing said needle comprises  
2 passing said needle through said first portion of the guide channels, through the wall of  
3 said first body duct, and into said second portion of the guide channels.

1 45. A method as in claim 40, wherein advancing the needles comprises  
2 unconstraining said needles so that the each needles assume an arcuate, everted  
3 configuration as they are passed forwardly.

1 46. A method as in claim 40, wherein advancing the needles comprises  
2 using a plunger having a tubular structure releasably coupled to said needle to push said  
3 needle along said path.

1 47. A method as in claim 40, wherein securing the sutures comprises  
2 removing said sutures from said guide channels by lifting the sutures out of the channels  
3 through a longitudinal slot running along a length of each of said guide channels.

1 48. A method as in claim 40, further comprising:  
2 providing a suturing device having an inner tube coaxially mounted within  
3 an outer tube, where at least one of said needles is made of a shape-memory alloy and is  
4 mounted on the inner tube; and  
5 extending said needles beyond the outer tube by relative motion between  
6 the needle and the outer tube, said needle extended to a configuration where a sharpened  
7 tip of the needle points substantially in a proximal direction.

1 49. A method as in claim 40, further comprising lifting said shaft  
2 structure in a proximal direction to pull the needles through the peripheral tissue  
3 surrounding the hole in the second body duct.

1 50. A method as in claim 40, further comprising everting the first body  
2 duct over said needles.

1 51. A method as in claim 40, further comprising using a breakaway  
2 catheter to facilitate introduction of the shaft structure into the second body duct.

1 52. A method as in claim 40, wherein securing said sutures comprises:  
2 collecting sutures carried near a sharpened tip of said needles; and

3 tying off the sutures to connect the body ducts together.

1 53. A method as in claim 40, wherein the second body duct comprises  
2 an artery.

1 54. A method as in claim 40, wherein the second body duct comprises  
2 the aorta.

1 55. A method as in claim 40, wherein said advancing and securing  
2 steps are performed on a beating heart.

1 56. A method as in claim 40, wherein said advancing and securing  
2 steps are performed on a stopped heart.

1 57. A method as in claim 40, wherein said positioning, advancing, and  
2 securing steps are performed minimally invasively.

1 58. A method as in claim 40, wherein said positioning, advancing, and  
2 securing steps are performed in an open surgery environment.

1 59. A method as in claim 40, wherein said positioning, advancing, and  
2 securing steps are performed through minimally invasive percutaneous openings in a  
3 chest of a patient.

1 60. A method for suturing an end of a first body duct to a hole in the  
2 side of a second body duct, said method comprising:  
3 using a needle driver to simultaneously pass a plurality of sutures through  
4 the end of the first body duct, inwardly through the hole of the second body duct, and  
5 outwardly through peripheral tissue surrounding the hole in the second body duct; and  
6 securing a portion of the suture outside of the first body duct to a portion  
7 of the suture outside of the peripheral tissue surrounding the hole in the second body duct.

1 61. A method as in claim 60, wherein a plunger is used to pass a  
2 plurality of needles through the end of the first body duct, wherein each of said needles  
3 carries one of said sutures.

1 62. A kit comprising:  
2 a graft suturing device adapted to deliver a plurality of needles;

3 instructions for use in suturing an end of a first body duct to a hole in the  
4 side of a second body duct comprising using the graft anastomosis device to  
5 simultaneously advance a plurality of needles radially into and forwardly out of the end of  
6 the first body duct and into the hole of the second body duct and then evert so that the  
7 needles will pass outwardly through tissue peripheral to the hole when the end of the first  
8 body duct is on the device adjacent to the hole in the second body duct; and  
9 a package adapted to contain the device and the instructions for use.

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